Atmospheric Phenomena

Detecting Nuclear Detonation in the Atmosphere: Weapons Phenomenology

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The development of sensors to detect atmospheric nuclear explosions in space satisfies an important national security need to monitor and verify international test ban treaties. Design and successful operation of these sensors requires a basic understanding of the source and its associated emissions, propagation of the signals to the detector, and the detailed nature of the natural and anthropogenic background in which they must operate. We develop models and computational tools to simulate all aspects of the treaty-monitoring problem from the source to the sensor. Our present emphasis is on predicting the optical pulse and electromagnetic pulse (EMP) produced by a nuclear detonation, but we have also worked on various aspects of acoustic wave propagation, simulations of bolide-Earth collisions, fireball physics, lightning physics, ionospheric physics, satellite data analysis, satellite system analysis, urban pollution analysis and modeling, and active space experiments such as chemical injections in the upper atmosphere.

Lightning is a major source of optical radio-frequency (RF) and x-ray impulses, and one of the goals of our program is to understand the fundamental nature of thunderstorm electrical discharges in order to develop lightning models that predict the associated electromagnetic emissions that are observed from space. For the past several years, we have addressed a number of issues related to the discrimination of the EMP produced by a nuclear detonation from the impulsive background generated by lightning discharges. We have generated detailed models to simulate the recently documented phenomena of high-altitude discharges termed “sprites,” “blue jets,” and “elves,” as well as of intracloud lightning.

We have also participated in ground-based and aircraft campaigns to obtain measurements of these phenomena and performed detailed comparisons between theory and observation. We continue to collaborate with our colleagues involved in the FORTE RF experiments to understand the origin of transionospheric pulse pairs and the source of lightning VHF emissions in general.

Infrasonic Monitoring

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The Los Alamos infrasound explosion-monitoring program, which has been in operation since 1981, is the longest operating program of this kind in the U.S. We operate six infrasonic arrays of sensors in the Western U.S., including two in Los Alamos and one on Ascension Island. Our fully digital system uses four infrasonic pressure sensors, which are laid out in a triangular shape, with a nominal baseline between sensors of about 1 km. Weather data are also monitored continuously. The Los Alamos site is very quiet, and routine signal amplitudes can be analyzed for S/N >1 for pressure amplitudes > 0.05 Pa (peak to peak).

Our data are sent daily to the Air Force Technical Applications Center (AFTAC), and they are sent directly from AFTAC to the Prototype International Data Center (PIDC) in Alexandria, Virginia. The PIDC has used our data to develop algorithms for infrasonic data processing, which will eventually be used in the operational phase of the IMS (international monitoring system) nuclear explosion monitoring effort. Data sources that we continue to monitor and log daily include large explosions at White Sands Missile Range, Space Shuttle launches and re-entry and other smaller missile launches, entry of large bolides (meteor fireballs) into the atmosphere, earthquakes, volcanic eruptions, gas-fire explosions, and similar events. For these events, we analyze the wave as well as the source properties.

Infrasonic Monitoring

In addition to monitoring these major events, we have the capacity to fully categorize infrasonic pressure sensors for amplitude and frequency using our system calibration chamber, the only one of its kind in North America. We collaborate with researchers in the U.S. and at various locations around the world (Sweden, Antarctica, Russia, France, etc.). For the Defense Threat Reduction Agency, DTRA, we recently performed a site noise for the official IMS infrasound array to be located on Eielson AFB in Alaska.

We continue an active theoretical and experimental research program on infrasound propagation (rays, normal modes, ray-mode theory, the parabolic equation, and others), as well as on noise reduction using pipes, hoses, and shelters. All aspects of the infrasonic source generation, propagation, and the strongly related detection and analysis problems have been actively pursued in our program. Recently, AFTAC has indicated a very strong interest in using the Los Alamos
infrasonic data for additional purposes for U.S. national monitoring needs.

In the last two years, we have begun modeling low-frequency acoustic signals from underground facilities to assist in characterizing these structures. We incorporate a modal approach to estimate signal amplitudes and frequencies from continuous and impulsive excitation. In another new area, we are focusing on near-field measurements of the low-frequency signals from rocket engines to determine the value of these signals for remote detection.

Hard and Deeply Buried Targets

Characterizing Underground Structures and Facilities

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We are focusing on new methods to detect human activity underground, with implications for detecting underground activities that might apply to defense work of other countries. In our first experiment of this series, we used narrow-band seismic array analysis to investigate a narrow-band signal centered at a frequency of 2.083 Hz, observed at the GERESS seismic array in Germany. We correctly detected the signal's source, machinery running synchronously with the electrical power network, located 300 km from the GERESS array. We determined that a second peak was statistically significant; we interpreted the second peak as either multipathing of a single signal or a second signal source. We also investigated other narrow peaks in the same data.

In our second study, we characterized seismic signals generated during tunnel boring of a new aqueduct west of Boston. Using seismographs at sites on the surface ranging from 0.5 to 3 km from the epicenter of the tunnel-boring machine (TBM), we recorded almost 40 hours of tunnel activity, including approximately 10 hours of machine operation. Our data indicate that the TBM signal falls below noise levels at 3 km from the TBM epicenter. Signal strength from the TBM may vary azimuthally, and we will explore this topic further. Spectra from short period sensors inside the tunnel show a set of harmonics that are present regardless of TBM activity, which suggests that these harmonics are caused by air pressure resonances within the tunnel. Recently, using a small array, we were able to detect the azimuth to the TBM to within about 8°. We will continue to use the recorded signals to describe the seismic characteristics of the TBM and other tunneling activities and to estimate parameters that describe tunnel geometry.